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An identification key for eggs and egg sacs of spiders of potential agroeconomic importance: a feasibility study

Richard S. Vetter[1,2] and **Devin P. Carroll**[3]: [1]Department of Entomology, University of California, Riverside, California 92521, USA. E-mail: rick.vetter@ucr.edu; [2]ISCA Technologies, P.O. Box 5266, Riverside, California 92517, USA; [3]6373 North Lead Avenue, Fresno, California 93711, USA

Abstract. Information regarding the eggs and egg sacs of spiders found in agricultural crops in the San Joaquin Valley of California's Central Valley is presented as a feasibility study to aid inspection of international commerce. Egg diameter showed little variation within a species and strong variation among species; hence, it is a valuable diagnostic feature. Egg quantity per sac and sac dimensions showed greater and overlapping variation, yet are still somewhat diagnostic depending on the species. Least diagnostic was the phenology of egg sac production, but this characteristic was still useful in determining that some species finish producing egg sacs prior to crop harvest, indicating that they would not be found in transported produce. A diagnostic key utilizing the most useful of these features is provided. Overall, it appears likely that if keys regarding spider eggs and egg sacs could be developed, they could provide useful information in a real world economic situation.

Keywords: Araneae, agriculture, international trade

International commerce has led to the inadvertent redistribution of animals and plants throughout the world. Although many of these transplanted organisms probably die without establishing a viable population, many well-known examples exist of colonization by non-native organisms with detrimental economic effect (Jenkins 1996) or the displacement of native species leading to global species homogenization (Vander Zanden 2005). This process has been exacerbated by faster shipping methods, which for spiders increases the chance of surviving a journey to a foreign port (Kobelt & Nentwig 2008). Considering some of the detrimental animals on the invasive species list, spiders pale in comparison with other creatures that negatively impact commerce. However, concern still exists when toxic species such as those of the genera *Latrodectus* or *Phoneutria* are transported (Ross 1988; Reed & Newland 2002; Craemer 2006; van Meurs 2006; Vetter & Hillebrecht 2008).

Accurate identification is a priority. The misidentification of the harmless ctenid spider *Cupiennius chiapanensis* Medina Soriano 2006 as a potentially dangerous confamilial *Phoneutria* spider delayed the unloading of 960 cases of bananas in Texas (market value: $26,400 USD) (R.S. Vetter unpublished data). In a second incident, a shipping firm was almost required to fumigate 20 truckloads of Mexican wicker furniture and develop a personnel protection program for their employees due to a misidentification involving the same two ctenid species (Vetter & Hillebrecht 2008). Hence, misidentification of spiders can lead to economic loss in international trade due to greater expenditure in protection, use of pesticide control measures, or delays in the unloading of goods, especially perishable produce.

As much as spiders may cause consternation in international shipping, of equally great vexation for cargo inspectors is the discovery of a spider egg sac in goods (Reed & Newland 2002; van Meurs 2006). Delays due to waiting on spider emergence can last several weeks before identification is possible, risking spoilage of perishable cargo. As one can imagine, identification of newly emerged spiderlings could be a daunting task, especially for someone lacking extensive arachnological skill, even if the person is familiar with the local spider fauna. This difficulty is exacerbated when the person attempting the identification is in an international port and may not have extensive taxonomic knowledge or literature of the spider fauna of the country of origin, if that literature even exists.

Because of this situation, keys for spider eggs and egg sacs could benefit inspectors of American cargo being readied for international shipment. As we were not aware of any such information in the open scientific literature, we undertook this study as a heuristic device to examine the feasibility of such a novel project. Our hope is that by documenting the feasibility of this task, it might lead to more research on this understudied topic.

METHODS

We collected gravid spiders or egg sacs with guarding females from March through September in 2011 and 2012 in commercial crops of apples, pomegranates, grapes, citrus, and pears in central California's San Joaquin Valley in the following counties: Kern, Tulare, Fresno, and Madera. We also collected additional egg sacs of unique construction and unquestionable identity without females, based on the junior author's 24 years of experience in San Joaquin Valley agriculture. For some species, spiders were maintained to procure egg sacs; however, we typically only used sacs if they were laid in the first two weeks of eaptivity because we attempted to get natural fecundity measures, whereas artificial feeding of captive spiders might result in higher or lower quantities. The *Tivyna* spiders were an exception, in which five egg sacs were taken from two females over several weeks. The salticids construct egg sacs that are similar in form to one another but vary in size such that field-collected sacs required guarding females to be seen or collected simultaneously to assure species identification. When necessary, we collected and reared uncommon spiders, such as *Metacyrba* species, in Riverside until they produced egg sacs in captivity. We

generated most of the data for western black widow spiders from field-collected egg sacs in the Riverside area that were collected for a study of egg sac parasitism (Vetter et al. 2012a). We developed a phenology of oviposition for several species based on the junior author's 24 years of field notes.

We measured egg sacs with digital calipers for length and width, or diameter if spherical. Where the egg sac was ensconced within a retreat (*Cheiracanthium* and salticids), we measured the length and width of the retreat, as we surmised that an inspector would interpret the entire structure as an egg sac, not just the packet of eggs contained therein. We opened egg sacs and measured egg diameters with a Leiea MZ16 microscope fitted with an ocular micrometer. We measured the diameter for any one egg as the randomly-oriented subspherical egg lay across the micrometer instead of specifically trying to find the maximum or minimum size. The rationale behind this type of technique was to duplicate how an inspector would measure eggs in a rapid fashion, rather than taking the time to position each egg such that its greatest diameter would align with the micrometer. Nonetheless, most eggs were spherical. One exception, the araneid *Metepeira*, had bean-shaped eggs where we measured the greatest length.

We measured 10 egg sacs per species, with some exceptions, and 30 egg diameters, 10 from each of three egg sacs. We did not collect more of a particular species due to the time-intensive nature of the study and other limitations; we targeted 10 sacs as a feasible number to give us satisfactory measures of variation within the population, although often a few extra sacs were collected before we were assured that our target number had been reached. Also, an upper limit was necessary; otherwise the abundance of the common species would overwhelm our collecting efforts. For the less common species, we measured 15 eggs if possible in case we did not get sufficient quantities of eggs from additional specimens. Where clutches contained few viable-looking eggs or sacs contained damaged eggs, we measured these eggs as well as possible, often using more than three egg sacs. Obviously for those species with fewer than 10 eggs per sac, we used more than three sacs to obtain 30 measurements.

We counted the number of eggs or spiderlings per sac. If the sac contents consisted of eggs, the quantity was immediately counted. If the eggs had developed into embryos (rudimentary legs visible on the side of the egg) or beyond, we carefully closed the sac and counted the number of spiders upon emergence. Where spiderlings emerged and no additional live spiderlings were thought to be present, we treated the egg sac as follows to recover dead spiderlings or infertile eggs. We dipped the egg sac in 70% ethanol to reduce hydrophobicity and then placed it into a small plastic petri dish. A few drops of commercial bleach (6% sodium hypochlorite) were placed on top of the sac to dissolve the spider silk (Vetter et al. 1996). After most of the sac had been dissolved, we doused the sac with 70% ethanol in the petri dish to eliminate many of the visually disruptive bubbles that form as a result of the bleach action. We then examined the contents of the petri dish under a mieroscope whereupon shriveled, infertile eggs or dead spiderlings were removed and counted. These were added to the total of live spiderlings previously recovered to determine the total egg quantity of a particular sac.

Voucher specimens of the spider species are deposited in the California Academy of Sciences.

KEY TO EGG SACS OF SPIDERS FOUND IN SAN JOAQUIN VALLEY AGROECOSYSTEMS. COMMON SPECIES ARE IN **BOLD** TYPE, UNCOMMON SPECIES IN REGULAR TYPE. SPECIES WITH AN ASTERISK (*) ARE KNOWN TO OVIPOSIT IN THE HARVESTABLE PORTION OF AGRICULTURAL CROPS DURING THE HARVEST SEASON.

1a– sac suspended in web 2
1b– sac attached to substrate 8
2a– sac >10 mm 3
2b– sac <8 mm 4
3a– sac spherical or teardrop shaped with tightly woven exterior (Fig. 1), eggs free inside . . . **Latrodectus hesperus* Chamberlin & Ivie 1935
3b– eggs covered with loose silk (Fig. 2), eggs bound together in large connected matrix (Fig. 3) . . . ***Neoscona oaxacensis*** (Keyserling 1863)
4a– sac not spherical, somewhat angular (Fig. 4) or resembling a two-colored seed pod (Fig. 5) 5
4b– sac spherieal or subspherical 6
5a– sac somewhat angular, often triangular to pentagonal, suspended from silk at points with seam around perimeter (Fig. 4) . . . . . ***Dictyna calcarata* Banks 1904** or **Mallos pallidus* (Banks 1904) (in part)
5b– bicolored sac resembles a seed pod with an outer shell (Fig. 5), multiple sacs often strung together in succession (Fig. 6), eggs bean-shaped . . . . . *Metepeira arizonica* Chamberlin & Ivie 1942
6a– sac brown, eggs mottled tan and brown and visible through silk covering of few flimsy strands (Fig. 7), laid March through June . . . . . ***Theridion melanurum* Hahn 1831**
6b– sac tan 7
7a– sac never covered nor associated with dead plant material, laid April to September (Fig. 8) . . . . . ***Theridion dilutum* Levi 1957**
7b– sac may or may not be covered or adjacent to dead plant material, laid September to October (Fig. 9, 10) . . . . . *Tidarren haemorrhoidale* (Bertkau 1880) or ***Cryptachaea porteri* (Banks 1896)**
8a– sac dome-shaped with conspicuous flat brim around circumference, pure white silk of paper-like texture (Fig. 11) 9
8b– sac not papery, silk fibers apparent 10
9a– sac about 6 mm in diameter, eggs 0.76 mm in diameter . . . . . *Meriola decepta* (Banks 1895)
9b– sac about 8 mm in diameter, eggs 0.99 mm in diameter . . . . . ***Trachelas pacificus* Chamberlin & Ivie 1935**
10a– sac tiny (<1.8 mm), peaked dome shape, contains two to five eggs (Fig. 12) . . . . . *Tivyna moaba* (Ivie 1947)
10b– sac not tiny (>2 mm) 11
11a– sac <4 mm, covered with flimsy silk, eggs usually visible through silk 12

11b– sac >4 mm in at least one dimension 13
12a– sac about as high as wide, with some angular edges (Fig. 13) . . . . . ***Dictyna calcarata*** or **Mallos pallidus* (in part)
12b– sac flat, usually in a depression, eggs covered by a few flimsy silk strands (Fig. 14) . . . . . ***Oecobius navus*** **Blackwall 1859**
13a– sac often camouflaged more than 50% with detritus (Fig. 15, 16), February to May . . ***Hololena nedra*** **Chamberlin & Ivie 1942**
13b– sac covered 0% to 50% with detritus 14
14a– sac under bark, retreat of flocculent cribellate silk (Fig. 17) . . . . . *Kukulcania geophila* (Chamberlin & Ivie 1935)
14b– sac may be under bark or not, not surrounded by flocculent cribellate silk 15
15a– silk retreat variable in shape, fills space in which it is built, silk easy to separate with forceps, usually a retreat within folded leaves (Fig. 18) or under bark or between grape berries . . . . . ***Cheiracanthium mildei*** or ***C. inclusum***
15b– retreat-like sac, flat, longer than wide (Fig. 19), silk difficult to separate with forceps (salticids) 16
16a– sac small containing fewer than 20 eggs of less than 0.9 mm diameter . . . . . ***Sassacus vitis*** **(Cockerell 1895)** or ***Metacyrba taeniola similis*** **Banks 1904**
16b– sac large containing more than 20 eggs of greater than 1.15 mm diameter . . . . . *Thiodina hespera* Richman & Vetter 2004, *Phidippus audax* (Hentz 1845), or *Phidippus johnsoni* (Peckham & Peckham 1883)

RESULTS

Egg sacs.—The above key reflects the diversity of the egg sacs of the San Joaquin Valley spider fauna, including such traits as placement of the sac (suspended in the web or attached to a surface), overall shape (spherical, angular), degree of silk used to cover eggs, egg color, and egg sac silk color. Initially, we surmised that there would be a great deal of uniformity among the egg sacs; however, this was not the case. Some singular species were unique in their sacs, such as the seed-pod type sac of *Metepeira arizonica* (Fig. 5) or the massive sacs of the western black widow (Fig. 1) and *Neoscona oaxacensis* (Fig. 2, 3). On the other end of the spectrum, the large number of salticids with difficult-to-rip, retreat-like sacs required additional discriminatory skills to differentiate species. In regard to salticid sacs, pulling the sac with a pair of forceps in east-west directions, for example, opens up a hole. Subsequent pulling in a north-south direction opens up the silk, but closes the hole made in the east-west direction. Subsequent pulling repeats this process such that it required many such frustrating manipulations before the eggs were exposed, however, it did provide identification of the sac as that of a salticid spider.

Eggs.—The diversity of egg features provided sufficient numerical variability to allow for separation of species. Egg diameter is a life history trait with small variation within a species (Table 1). However, among the different species, egg diameter greatly varied from 0.39 ± 0.065 mm eggs of *Tivyna moaba* to the 1.24 ± 0.048 mm eggs of *Thiodina hespera*. However, we could discern with the unaided eye that egg diameter differences existed when two western black widow egg sacs were consecutively opened, measured, and the contents mixed in one petri dish. Therefore, we measured 50 western black widow eggs due to the greater variation.

Most eggs were glossy white or pearlescent, however, color differences provided useful diagnostic information for some species. The eggs of *Theridion melanurum* are mottled tan and brown and appear dark through the few silk strands holding them together.

Another variable that can be useful to exclude species from identification is the number of eggs per sac; however, this was more variable than egg diameter (Figs. 20 & 21). The smallest fecundity was recorded for *Tivyna moaba* with 3.6 eggs per sac (Fig. 20) ranging up to the most fecund spiders, *Neoscona oaxacensis* (mean = 230 eggs with a maximum of 622 in one sac) and the western black widow (mean = 283 with a maximum of 409 in one sac) (Fig. 21).

Seasonality of oviposition.—The seasonality of oviposition likewise provides characters useful in the key (Fig. 22). Some species (*Theridion melanurum* and *Hololena nedra*) are not a concern in harvested produce because they terminate oviposition prior to harvest season.

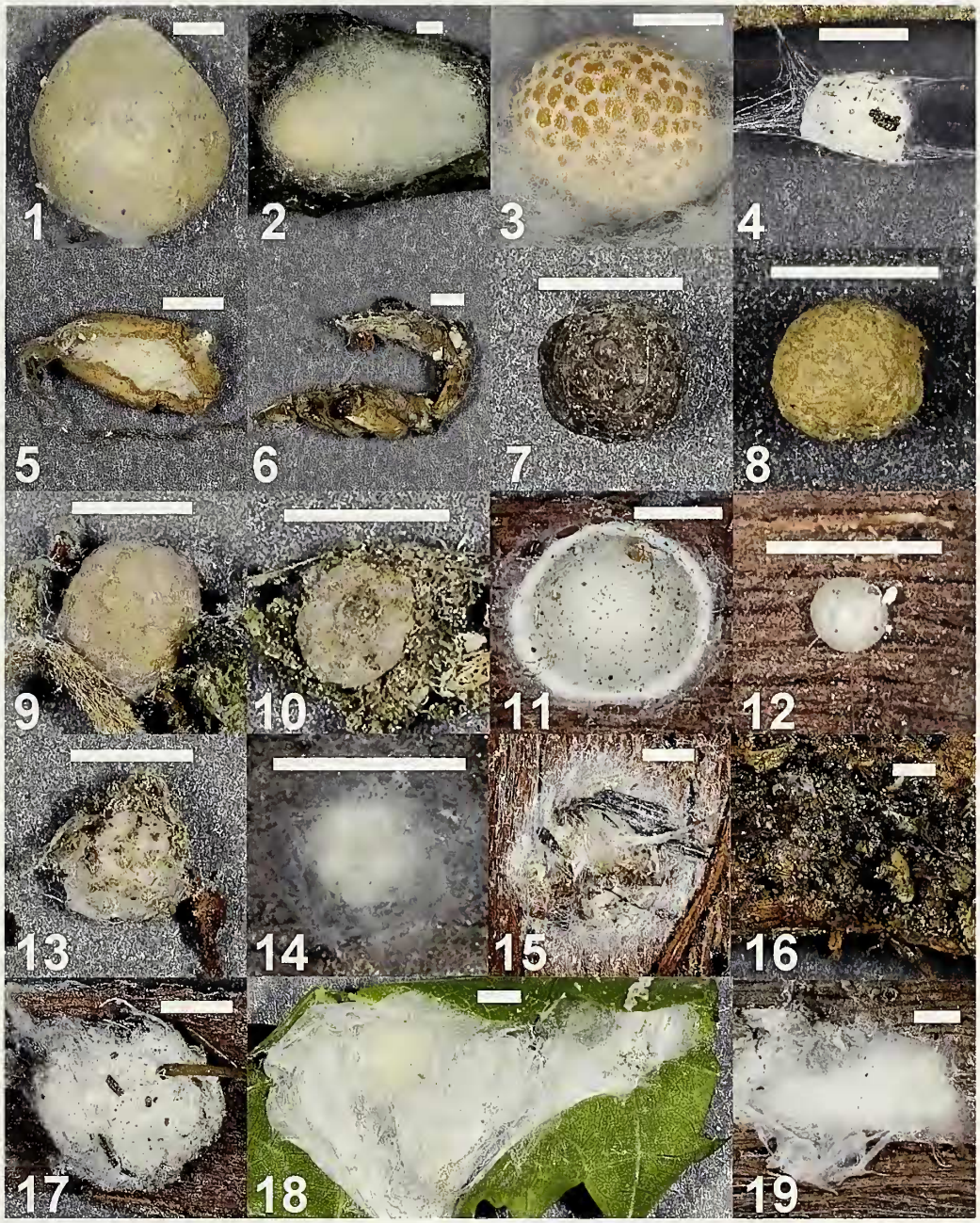
DISCUSSION

There are sufficient differences among spider egg sacs in morphology, egg diameter, number of eggs per sac and seasonal occurrence, that building a key and series of graphs and tables delineating these differences would be a useful and feasible project to identify spider species from a particular ecosystem. Some differences such as egg sac construction or egg shape could be diagnostic for the potential spider fauna of a region. However, one major caveat is that the spider fauna of the area of interest should be well documented prior to or generated during the course of the study. In this study, we included 22 species by searching several different crops via hand collection and based on the junior author's knowledge of the spider fauna of the area. In comparison, the studies of Costello and Daane (1995, 1997, 1998, 2003) involving at least four years of spider collecting from vineyards in several areas of the San Joaquin Valley with multiple sampling methods listed 29 species of spiders that potentially could be found.

Eggs diameters for most of the species that we examined had very little intraspecific variation (Table 1). Measuring a sample from a sac of unknown species should eliminate many species from consideration. Egg quantity per sac is obviously much more variable (Figs. 21 & 22) and hence, less diagnostic. However, it can be used to narrow the list of potential taxa. For example, an egg sac containing 30 eggs would surely exclude *Tivyna moaba, Oecobius navus, Mallos pallidus, Metacyrba taeniola similis* and *Sassacus vitis* as possible candidates.

Seasonality of egg sac production can also be an important factor. In the case of produce, the concern for egg sacs typically will be around the time of harvest, which for most commodities is summertime. Species that typically lay their eggs in the spring and terminate oviposition well before the harvest period such that they are unlikely to contaminate a cargo shipment can be removed as potential contaminants of shipped goods.

Location of oviposition also can be critical for assessing the value of a spider species as a potential pest in transported produce. For example, in vineyards, *Kukulcania geophila* only



Figures 1–19.—Egg sacs of spiders from San Joaquin Valley agricultural fields. Scale bar = 3 mm for all images. 1. *Latrodectus hesperus*. 2. *Neoscona oaxacensis*. 3. Exposed eggs of *Neoscona oaxacensis* in a connected matrix. 4. *Dictyna calcarata* sac when suspended in web. 5. Seed pod-like sac of *Metepeira arizonica*. 6. Several sacs of *Metepeira arizonica* strung together. 7. *Theridion melanurum*. 8. *Theridion dilutum*. 9. *Tidarren haemorrhoidale* sac with attached vegetation. 10. *Cryptachaea porteri* sac with attached vegetation. 11. *Trachelas pacificus*. 12. *Tivyna moaba*. 13. *Dictyna calcarata* sac when attached to substrate. 14. *Oecobius navus*. 15. *Hololena nedra* sac with about 50% detritus coverage. 16. *Hololena nedra* sac with about 100% detritus coverage. 17. *Kukulcania geophila* sac under bark. 18. *Cheiracanthium mildei* sac in the cavity of a curled leaf. 19. Sac of salticid spider.

deposits eggs under the bark of grape vines, so it could easily be excluded from the list of species contaminating shipments of produce. Additional biological knowledge may reduce concern over finding particular species in cargo. Although yellow sac spiders, *Cheiracanthium* spp., lay egg sacs in leaves of crops, the female guards the eggs. If a female is forced to abandon her egg sac or is killed, this would portend well for transported goods because *Cheiracanthium* spiderlings cannot emerge from the egg sac without the mother's help (Peck & Whitcomb 1970) and will die trapped inside.

Accurate identification of spiders should be critical for inspectors of imported cargo where the incorrect inclusion of a misidentified species might artificially and unnecessarily inflate the number of species of concern. Two examples, identified by New Zealand personnel, include *Latrodectus mactans* (Fabricius) 1775 and *L. geometricus* C.L. Koch 1941,

Table 1.—Egg diameters and egg sac dimensions for spiders found in San Joaquin Valley agroecosystems. Species are listed in increasing size of egg diameter. Sample size for eggs is 30 unless otherwise noted in parentheses next to the species name. The bean-shaped eggs of *Metepeira* are listed by greatest length only. Egg sac dimensions are presented for shortest and longest average ± SD measurement; if only one average is given, the egg sac is spherical or subspherical. Sample size for egg sacs follow egg sac dimensions in parentheses. Some egg sacs could not be measured as they were destroyed or misshapen during collecting and, therefore, sample sizes will not match in comparison to other portions of the study.

Species	Family	Egg diameter (mm)	Egg sac dimensions (mm)
Tivyna inoaba (5)	Dictynidae	0.389 ± 0.065	1.4 ± 0.4, 1.4 ± 0.4 (4)
Theridion melanurum	Theridiidae	0.539 ± 0.029	3.2 ± 0.6 (9)
Theridion dilutum	Theridiidae	0.555 ± 0.031	2.4 ± 0.4 (16)
Oecobius navus	Oecobiidae	0.555 ± 0.024	3.1 ± 0.5; 3.9 ± 0.5 (14)
Dictyna calcarata	Dictynidae	0.564 ± 0.024	3.3 ± 0.5; 3.8 ± 0.4 (10)
Tidarren haemorrhoidale	Theridiidae	0.566 ± 0.017	3.4 ± 0.6 (10)
Cryptachaea porteri	Theridiidae	0.594 ± 0.017	2.8 ± 0.6 (6)
Mallos pallidus	Dictynidae	0.614 ± 0.039	2.9 ± 0.8; 3.7 ± 0.7 (5)
Meriola decepta (4)	Corinnidae	0.764 ± 0.021	6.4; 6.4 (1)
Sassacus vitis	Salticidae	0.818 ± 0.029	7.0 ± 1.8; 13.5 ± 3.4 (11)
Metacyrba taeniola similis	Salticidae	0.868 ± 0.047	8.7 ± 1.9; 13.5 ± 5.0 (4)
Neoscona oaxacensis	Araneidae	0.950 ± 0.092	17.1 ± 1.0; 23.8 ± 6.0 (8)
Metepeira arizonica	Araneidae	0.958 ± 0.035	3.9 ± 0.6; 8.7 ± 1.5 (11)
Trachelas pacificus	Corinnidae	0.989 ± 0.042	7.7 ± 1.3; 8.4 ± 1.1 (12)
Latrodectus hesperus (50)	Theridiidae	1.044 ± 0.061	10.8 ± 1.5; 13.1 ± 2.2 (15)
Cheiracanthium mildei	Miturgidae	1.081 ± 0.064	17.5 ± 3.5; 25.0 ± 7.1 (2)
Hololena nedra	Agelenidae	1.135 ± 0.047	10.8 ± 1.5; 13.11 ± 2.2 (15)
Kukulcania geophila (10)	Filistatidae	1.141 ± 0.029	7.1; 8.1 (1)
Phidippus johnsoni	Salticidae	1.212 ± 0.075	24.3 ± 4.0; 40.0 ± 0.0 (3)
Phidippus audax (15)	Salticidae	1.216 ± 0.069	33.0, 33.0 (1)
Thiodina hespera (15)	Salticidae	1.243 ± 0.048	—

which were reported to have been intercepted from California produce (Reed & Newland 2002). This is highly unlikely. First, *L. mactans* is not found in the western United States and we know of no records of it ever being collected in California. We surmise that misidentification occurred because the diagnostic feature of *L. mactans* (a red dot anterior to the anal tubercle on the dorsal abdominal surface) was actually the rarely-occurring remnant juvenile coloration of *L. hesperus* (Kaston 1970, R.S.Vetter pers. observ.), the only black widow species in California. A similar misidentification as *L. mactans* was made for a *Latrodectus* spider (surely *L. hesperus*) found in southern California produce transported to Ireland (Ross 1988). Second, the pantropical *L. geometricus*, has only recently been found in California (Vincent et al. 2008). It was not known anywhere in California at the time of the report of Reed & Newland (2002) and, as of 2012, it has not been found in Central Valley agricultural areas. Additionally, it may never colonize agricultural areas because, in southern California, it is restricted almost entirely to urban locations (Vetter et al. 2012b). We speculate that this was probably

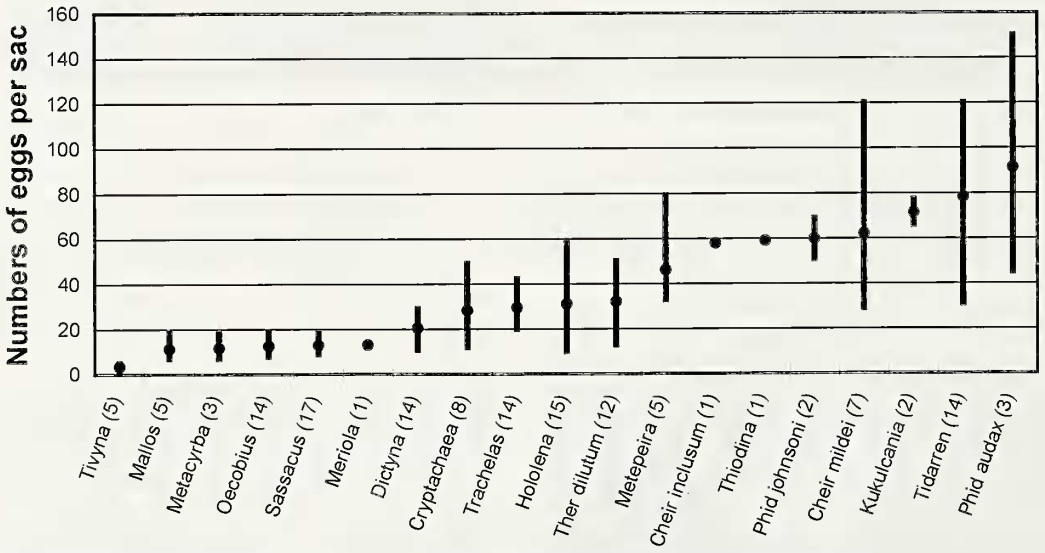


Figure 20.—Minimum, average and maximum eggs per sac for San Joaquin Valley agroecosystem spiders that lay less than 160 eggs per sac. The number in parentheses following the taxon name is the sample size.

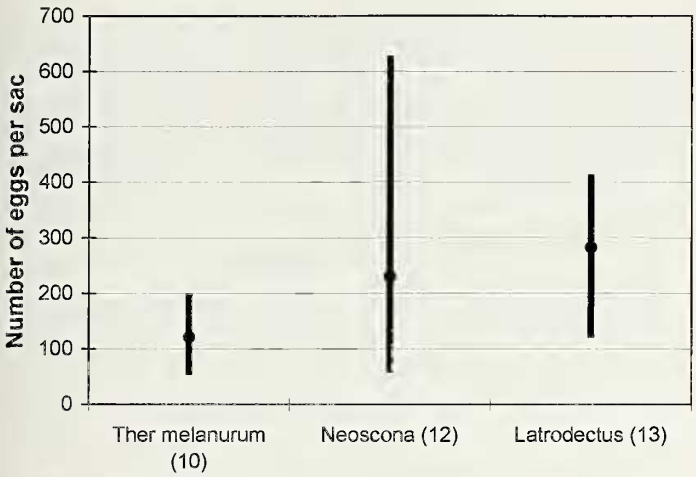


Figure 21.—Minimum, average and maximum eggs per sac for San Joaquin Valley agroecosystem spiders that can lay more than 160 eggs per sac. The number in parentheses following the taxon name is the sample size.

another misidentification of an immature *L. hesperus*, which has similarities in the striped pattern (Vetter 2012) and is frequently mistaken as *L. geometricus* by non-arachnologists (R.S.Vetter pers. observ.). Interestingly, although misidentifications have been made involving these three *Latrodectus* spiders, their egg sacs are easy to differentiate from one another: *L. hesperus* (yellowish tan, spherical or teardrop shaped), *L. mactans* (white, spherical or teardrop shaped), *L. geometricus* (tan, spherical and covered with silk spikes). Yet both non-Californian species were on New Zealand's list of concern for California trade (Reed & Newland 2002). We feel that with more information such as a key to eggs and egg sacs of spiders that these mistakes could be minimized or prevented.

Several limitations are evident in this study. First, a major caveat affecting the utility of the information presented here is that identification of a spider to species involving examination of an egg sac collected in the real world situation of a cargo hold requires that the sac sustains little damage during transport. This may be an overly optimistic supposition as sacs may get crushed during produce harvesting and processing or when cargo shifts during transport. Then again, if the sac is destroyed, it will not produce spiderlings to unleash into the new habitat, although the presence of a crushed egg sac may still raise concerns that there are more in the cargo undiscovered. One of us (R.S.Vetter) is currently undertaking a study regarding spiders found in international cargo brought into North America. On four occasions, egg sacs have been found on bananas, some with live spiderlings, including some of these discovered by the homeowner after taking fruit home (which, of course, caused considerable excited concern). Second, another aspect of elimination of species from consideration is that not every species in an agricultural area uses the harvestable portions of the plant for oviposition. This is positive from the standpoint that these spiders can be removed from the list of potentially imported

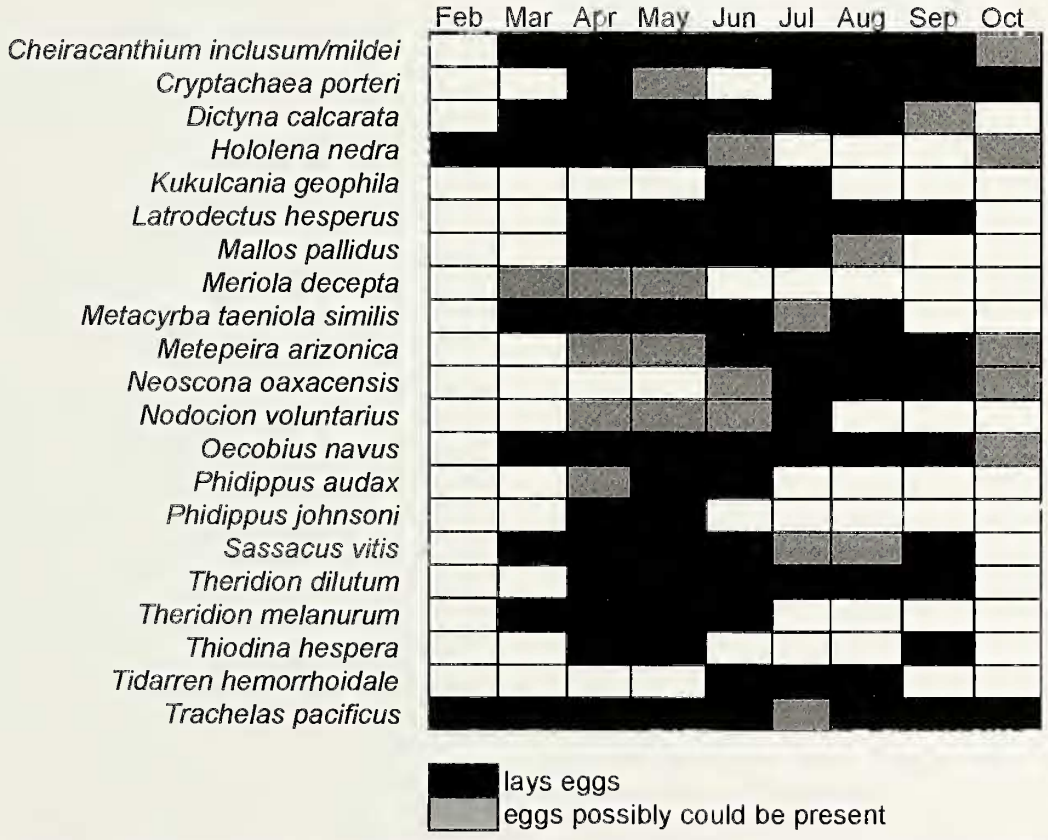


Figure 22.—Seasonality of egg laying for San Joaquin Valley agroecosystem spiders based on the 24-year experience of the junior author with months marked as eggs present (black) or eggs possibly present (gray). Some of these species listed here are absent from previous figures because their egg sacs were not detected during the 2-year course of this study.

egg sacs; however, it still does not allow sacs to be easily located in the field and measured so that information may be presented in order to exclude them more definitively from the list of potential transportable species. Although gnaphosid spiders were sufficiently common in San Joaquin Valley fields, their egg sacs were not discovered during the 2-year duration of this study. We also were not able to proeure egg sacs from female specimens that were collected. Possibly some species only hunt for food on the crop but lay their eggs under rocks or dirt clods or in places other than the fruit or vegetables that were being grown, or camouflage their sacs so well that they cannot be easily detected. Third, we had low sample sizes for some species because they were uncommon in the fields or they did not oviposit where their eggs could easily be found. A larger sample size for each species would provide more accurate information, especially for the number of eggs per egg sac. If a future project is deemed feasible, sufficient funding should override this deficiency. Fourth, we only looked at egg sacs and eggs; egg sacs do not always contain eggs. Some of the information provided here becomes superfluous once embryos develop and especially if the sac contains spiderlings. The degree of differentiation presented here could be further enhanced with additional life history characteristics such as description of the second instars. This would benefit the discrimination of the salticids in particular. For example, although *Sassacus vitis* and *Metacyrba taeniola similis* eggs and egg sacs are difficult to distinguish from one another, *Metacyrba* spiderlings emerging from the sac resemble the adults as almost exact miniatures such that they were recognizable to genus. Similarly, although *Thiodina hespera* and the two *Phidippus* species had equivalent-sized eggs and similar retreats, *T. hespera* spiderlings emerge as very pale individuals and have a partial complement of the diagnostic bulbous setae on the ventral surface of Tibia I, whereas *Phidippus* spiderlings are dark (R.S. Vetter, personal observation). Finally, DNA determination of adults might allow one to differentiate the difficult-to-separate species of egg saes.

To our knowledge, this is the first time that a diagnostic key for spider eggs and egg sacs for species separation has been generated in the open scientific literature. The only other readily accessible souree of information for diseerning spider egg sacs is a field guide to arthropod tracks and signs for the curious nature enthusiast which covers North America and has a modicum of information on spiders (Eiseman & Charney 2010). Although building a diagnostic key for eggs and egg sacs is a tedious and time consuming task, in some commercial venues there may be a need for developing such differentiation devices. The eventual determination of such a project will probably be driven by economie need and feasibility. Although this study was undertaken as a feasibility study, we feel that it is a good first effort and should offer some practical value for inspectors in central California's San Joaquin Valley.

We also hope that this study might spur other researchers to consider developing similar research along these lines because the documentation of different egg demographics might be an interesting and useful addition to the arachnological field in arenas of pure and applied research. One of the most useful functions of this study was to pare down the number of spiders from an overall species list to those that are candidates for ovipositing in harvestable crops. By providing information regarding seasonality and location of oviposition, the final number of species that might be found by inspectors in an agricultural crop is a small subset of the total potential species in the spider fauna of that geographic area, which should streamline identification efforts.

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LITERATURE CITED

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